1. **(b):** The electric potential inside is same as that at the surface. Hence,

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{R}\right) = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{10}\right)$$

Outside potential is given by

$$V' = \frac{1}{4\pi\varepsilon_0}\frac{q}{15} = \frac{2}{3}\left[\frac{1}{4\pi\varepsilon_0}\times\frac{q}{10}\right] = \frac{2V}{3}$$

2. **(d):** The particle is moving only along x-axis, whereas the location along y axis does not change. Displacement of particle along x-axis in time $t = 2$ s $= 2 \times 2 = 4$ units. Therefore, position coordinates of particle after 2 s is (4, 20).

3. **(c):** Let θ be the angle which vector $\vec{A}$ makes with x-axis. Then,

$$\cos\theta = \frac{A_x}{A} = \frac{4}{\sqrt{4^2+3^2+12^2}} = \frac{4}{13}$$

$$\therefore \quad \theta = \cos^{-1}\left(\frac{4}{13}\right)$$

4. **(b):** $(m+1)$VSD $= m$MSD

$$\therefore \quad 1\,\text{VSD} = \left[\frac{m}{(m+1)}\right]\text{MSD}$$

Least count = 1 MSD – 1 VSD

$$= 1\,\text{MSD} - \left(\frac{m}{(m+1)}\right)\text{MSD}$$

$$= \frac{1}{(m+1)}\text{MSD} = \frac{d}{(m+1)}$$

5. **(c):** Magnetic field at any point on the axis of current carrying coil at a distance x from the centre is given by

$$B_a = \frac{\mu_0 N I r^2}{2(r^2+x^2)^{3/2}}$$

where r is the radius of the coil.

At the centre, $x = 0$

$$\therefore \quad B_c = \frac{\mu_0 N I r^2}{2r^3} = \frac{\mu_0 N I}{2r}$$

$$\therefore \quad \frac{B_c}{B_a} = \frac{\mu_0 N I}{2r}\times\frac{2(r^2+x^2)^{3/2}}{\mu_0 N I r^2} = \frac{(r^2+x^2)^{3/2}}{r^3}$$

Given, $B_c = 5\sqrt{5}\,B_a$

$$\therefore \quad 5\sqrt{5} = \frac{(r^2+x^2)^{3/2}}{r^3} = \frac{(100+x^2)^{3/2}}{1000}$$

Squaring on both sides, we get

$$125 = \frac{(100+x^2)^3}{10^6}$$

or $125 \times 10^6 = (100 + x^2)^3$

or $100 + x^2 = 5 \times 10^2 = 500$

$\therefore \quad x = 20$ cm

6. **(d):** The speed of electromagnetic waves in a medium of relative permittivity ε_r and relative permeability μ_r is given by

$$v = \frac{1}{\sqrt{\varepsilon_r\varepsilon_0\mu_r\mu_0}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}} \qquad \left(\because c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}\right)$$

Here $\varepsilon_r = 2.14$, $\mu_r = 1.3$

$$\therefore \quad v = \frac{3\times10^8\ \text{m s}^{-1}}{\sqrt{2.14\times1.3}} = 1.8\times10^8\ \text{m s}^{-1}$$

7. **(b):** Let $t = kG^p c^q h^r$

where k is the dimensionless constant.

Equating dimensions on both sides, we get

$[t] = [M^{-1}L^3T^{-2}]^p[LT^{-1}]^q[ML^2T^{-1}]^r$

$[t] = [M^{-p+r}\,L^{3p+q+2r}T^{-2p-q-r}]$

Applying principle of homogeneity, we get

$-p + r = 0$ ...(i)

$3p + q + 2r = 0$ ...(ii)

$-2p - q - r = 1$ ...(iii)

Solving (i), (ii) and (iii), we get

$$p = \frac{1}{2}, q = -\frac{5}{2}, r = \frac{1}{2}$$

$$\therefore \quad t = \sqrt{\frac{Gh}{c^5}}$$

8. **(d):** The time period of geostationary satellite is 24 hours. Its period of revolution around the earth should be the same as that of the earth about its axis *i.e.*, 24 hours.

9. **(a):** Let $\lambda_A = \lambda \therefore \lambda_B = 2\lambda$.

If N_0 is total number of atoms in A and B at $t = 0$, then initial rate of disintegration of $A = \lambda N_0$, and initial rate of disintegration $B = 2\lambda N_0$

As $\lambda_B = 2\lambda_A \quad \therefore T_B = \frac{1}{2}T_A$

i.e. Half life of B is half the half life of A.

After one half life of A

$$\left(-\frac{dN}{dt}\right)_A = \frac{\lambda N_0}{2}$$

Equivalently, after two half lives of B

$$\left(-\frac{dN}{dt}\right)_B = \frac{2\lambda N_0}{4} = \frac{\lambda N_0}{2}$$

Clearly, $\left(-\frac{dN}{dt}\right)_A = -\left(\frac{dN}{dt}\right)_B$

after $n = 1$ *i.e.* one half life of A.

10. **(d):** Work done, $W = -MB\cos(\theta_2 - \theta_1)$

$= -MB\cos(360° - 0°)$

$= 0$

11. **(b):** Horizontal range, $R = \dfrac{u^2\sin 2\theta}{g}$

Time of flight, $T = \dfrac{2u\sin\theta}{g}$

where u is the velocity of the projection and θ is the angle of projection with the horizontal.

$$R = \frac{u^2 \sin 2\theta}{g} \quad \text{or} \quad R = \frac{2u^2 \sin\theta \cos\theta}{g}$$

$$\text{or} \quad \frac{R}{2\cos\theta} = \frac{u^2 \sin\theta}{g} \qquad \text{....(i)}$$

$$T = \frac{2u \sin\theta}{g} \quad \text{or} \quad T^2 = \frac{4u^2 \sin^2\theta}{g^2}$$

$$T^2 = \frac{4}{g}\left(\frac{u^2 \sin\theta}{g}\right)\sin\theta$$

$$= \frac{4}{g}\left(\frac{R}{2\cos\theta}\right)\sin\theta \qquad \text{(Using (i))}$$

$$\text{or} \quad T^2 = \frac{2R}{g}\tan\theta \quad \text{or} \quad R = \frac{gT^2}{2\tan\theta}$$

12. **(a)** : Here, $x = At^3 + Bt^2 + Ct + D$

Velocity, $v = \frac{dx}{dt} = \frac{d}{dt}[At^3 + Bt^2 + Ct + D]$

or $v = 3At^2 + 2Bt + C$

At time $t = 4$ s

$v = 3A(4)^2 + 2B(4) + C$

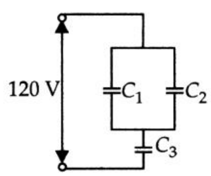
or $v = 48A + 8B + C$

$\because$ $A = 1, B = 4, C = -2$

$\therefore$ $v = 48(1) + 8(4) + (-2) = 78 \text{ m s}^{-1}$

13. **(a)** : $I_{\text{rms}_1} = \frac{I_{01}}{\sqrt{2}} = \frac{I_0}{\sqrt{2}}; I_{\text{rms}_2} = \frac{I_{02}}{\sqrt{2}} = \frac{I_0}{\sqrt{2}}$

$\therefore$ Ratio = 1 : 1

14. **(b)** : 

Capacitors C_1 and C_2 are in parallel and their combination is in series with capacitor C_1. Therefore, the equivalent capacitance of the circuit is

$$C_{eq} = \frac{(C_1 + C_2)C_3}{C_1 + C_2 + C_3} = \frac{(10 + 20)(15)}{10 + 20 + 15} = 10\ \mu\text{F}$$

The charge flowing in the circuit is

$Q = C_{eq}V = (10\ \mu\text{F})(120\ \text{V}) = 1200\ \mu\text{C}$

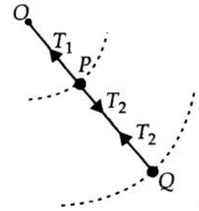
The potential difference across C_3

$$= \frac{Q}{C_3} = \frac{1200\ \mu\text{C}}{15\ \mu\text{F}} = 80\ \text{V}$$

15. **(b)** : n-type semiconductor is obtained when Si or Ge (tetravalent) is doped with pentavalent inpurities like As, Sb, P, etc.

16. **(a)**

17. **(b)** : Centripetal force = $mr\omega^2$



Let m be mass of each sphere and T_1 be the tension in the string between O and P and T_2 be the tension in the string between P and Q respectively. The equations of motion are

For P, $T_1 - T_2 = m \times 1 \times \omega^2$ ...(i)

For Q, $T_2 = m \times 2 \times \omega^2$ ...(ii)

Adding (i) and (ii), we get

$T_1 = 3m\omega^2$

$$\therefore \quad \frac{T_2}{T_1} = \frac{2m\omega^2}{3m\omega^2} = \frac{2}{3}$$

18. **(b)** : Let x alpha particles and y beta particles are emitted.

$\therefore$ ${}_{88}A^{196} \longrightarrow {}_{78}B^{164} + x\ {}_2\text{He}^4 + y\ {}_{-1}e^0$

According to conservation of charge number, we get

$88 = 78 + 2x - y$ ...(i)

According to conservation of mass number, we get

$196 = 164 + 4x + 0$ ...(ii)

Solving (i) and (ii), we get

$x = 8, \ y = 6$

Hence, 8α-particles and 6β-particles are emitted.

19. **(c)** : In an ideal transformer, there is no power loss. The efficiency of an ideal transformer is $\eta = 1$ (*i.e* 100%) *i.e.* input power = output power.

20. **(a)** : Young modulus, $Y = \frac{FV}{A^2 \Delta l}$

Y, F and V are constants

$$\therefore \quad \Delta l \propto \frac{1}{A^2} \quad \text{or} \quad \Delta l \propto \frac{1}{D^4}$$

$$\therefore \quad \frac{\Delta l_A}{\Delta l_B} = \frac{D_B^4}{D_A^4} = \frac{D_B^4}{\left(\frac{1}{2}D_B\right)^4} = 16$$

Note: $Y = \frac{F}{A} \times \frac{l}{\Delta l}$

$V = Al$ or $l = \frac{V}{A}$

$$\therefore \quad Y = \frac{FV}{A^2 \Delta l}$$

21. **(a)** : Here, emf of each cell = ε

Internal resistance of each cell = r

Total internal resistance of 8 cells are connected in series is

$r_{\text{series}} = 8r$

If the polarity of two cells are reversed, then the total internal resistance of the cells is

$r'_{\text{series}} = 8r$

i.e., there is no effect on the total internal resistance of the cells.

22. **(d)** : Here bridge is balanced, no current flows through resistance R', hence R' will not be involved in the total resistance of network.

The equivalent resistance of the network

$$= \frac{2R \times 4R}{2R + 4R} = \frac{4R}{3}$$

23. **(d)** : Force on 10 kg mass = $10 \times 12 = 120$ N

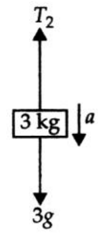
The mass of 10 kg will pull the mass of 20 kg in the backward direction with a force of 120 N.

$\therefore$ Net force on mass 20 kg = $200 - 120 = 80$ N

Its acceleration $= \frac{80 \text{ N}}{20 \text{ kg}} = 4 \text{ m s}^{-2}$

24. **(a) :** Let a be the common acceleration of the system.

$a = \frac{7-5}{7+5}g = \frac{2}{12}g = \frac{1}{6}g$



The equation of motion of 3 kg mass is

$3g - T_2 = 3a$

or $T_2 = 3g - 3\left(\frac{g}{6}\right)$

or $T_2 = \frac{5g}{2} = \frac{5}{2} \times 9.8 \text{ N} = 24.5 \text{ N}$

25. **(b):** Excess pressure difference across the interface is $\frac{4S}{2r} - \frac{4S}{3r} = \frac{4S}{6r}$ which must be $\frac{4S}{R}$ where R is the radius of curvature at the interface. This gives $R = 6r$.

26. **(a) :** $R_1 = \frac{\rho l_1}{A_1}; R_2 = \frac{\rho l_2}{A_2}$

$R_1 = \frac{\rho l_1}{A_1} \times \frac{l_1}{l_1} = \frac{\rho l_1^2}{V}$

$R_2 = \frac{\rho l_2}{A_2} \times \frac{l_2}{l_2} = \frac{\rho l_2^2}{V}$

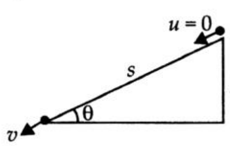
$\therefore \quad \frac{R_1}{R_2} = \frac{l_1^2}{l_2^2} = 4$

For maximum resistance, $l_1 = 4$ cm

For minimum resistance, $l_2 = 2$ cm

$\therefore \quad \frac{R_1}{R_2} = \frac{16}{4} = \frac{4}{1}$

27. **(d):**



From work-energy principle,

$$\frac{1}{2}mv^2 = mgh - f \times s = mgh - (\mu mg\cos\theta) \times \frac{h}{\sin\theta}$$

$v = \sqrt{2gh - 2\mu gh\cot\theta}$

i.e. $v \propto m^0$.

28. **(c) :** Let $\vec{A} = \hat{i} + \hat{j}$

$\vec{B} = \hat{j} + \hat{k}$

$\therefore \quad |\vec{A}| = \sqrt{(1)^2 + (1)^2} = \sqrt{2}$

$|\vec{B}| = \sqrt{(1)^2 + (1)^2} = \sqrt{2}$

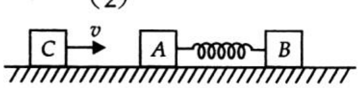
Let θ be the angle between the vectors $\vec{A}$ and $\vec{B}$. According to the defination of scalar product

$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}|\cos\theta$

or $\cos\theta = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}||\vec{B}|} = \frac{(\hat{i}+\hat{j}) \cdot (\hat{j}+\hat{k})}{(\sqrt{2})(\sqrt{2})} = \frac{1}{2}$

$\therefore \quad \theta = \cos^{-1}\left(\frac{1}{2}\right)$ or $\theta = 60°$

29. **(a) :**



Because the masses of C and A are same and initially the block A is not in motion, hence when the block C collides elastically to block A, it itself gets stopped and transfers its momentum mv and K.E. $\left(= \frac{1}{2}mv^2\right)$ totally to block A. In this position, B is stationary and spring is in its normal state. Hence, the instantaneous momentum of the system is mv and K.E. is $\frac{1}{2}mv^2$. Now the spring is compressed and block B also comes in motion. Suppose the instantaneous velocity of A and B after collision be v' and maximum compression in the spring is x. As no external force acts on the system, according to law of conservation of linear momentum we get,

$mv = mv' + mv'$

or $v = 2v'$ ...(i)

According to law of conservation of mechanical energy, we get

$$\frac{1}{2}mv^2 = \frac{1}{2}mv'^2 + \frac{1}{2}mv'^2 + \frac{1}{2}kx^2$$

or $v^2 = 2v'^2 + \frac{kx^2}{m}$ ...(ii)

From eq. (i), $v' = \frac{v}{2}$

$\therefore \quad v^2 = \frac{v^2}{2} + \frac{kx^2}{m}$

or $\frac{kx^2}{m} = \frac{v^2}{2}$ or $x = v\sqrt{\frac{m}{2k}}$

30. **(a) :** Here,

$\lambda = 600 \text{ nm} = 600 \times 10^{-9}$ m

$= 6000 \times 10^{-10}$ m

θ = angular separation = 0.2°

D = distance of screen from the slits = 1 m

μ = R.I. of water $= \frac{4}{3}$.

θ' = angular width of the fringes in water = ?

$\therefore \quad \lambda' = \frac{\lambda}{\mu}$

Fringe width β is given by

$\beta = \frac{\lambda D}{d}$

or $\frac{\beta}{D} = \frac{\lambda}{d}$ ...(i)

Angular width, $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$ (Using (i)) ...(ii)

Also $\theta' = \frac{\lambda'}{d}$ ...(iii)

Dividing (iii) by (ii), we get

$$\frac{\theta'}{\theta} = \frac{\lambda'}{\lambda} = \frac{\lambda/\mu}{\lambda} = \frac{1}{\mu}$$

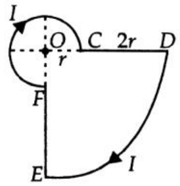
or $\theta' = \frac{\theta}{\mu} = \frac{0.2°}{\left(\frac{4}{3}\right)} = \frac{0.2 \times 3}{4} = 0.15°$

31. (a) : For a given T, $V \propto \frac{1}{P}$

$\therefore \quad \frac{V_2}{V_1} = \frac{P_1}{P_2}$

For a given T, $V_2 > V_1$ so $P_1 > P_2$

32. (b) :



Refer figure. The angle subtended by arc DE at O is $\frac{\pi}{2}$ and by arc FC at $O = \frac{3\pi}{2}$.

The effective magnetic field at O is

$$B = B_{DE} + B_{FC}$$

$$= \frac{\mu_0}{4\pi}\frac{I}{3r} \times \frac{\pi}{2} + \frac{\mu_0}{4\pi}\frac{I}{r} \times \left(\frac{3\pi}{2}\right) = \frac{\mu_0 I}{8r}\left[\frac{1}{3} + 3\right]$$

$$= \frac{5\mu_0 I}{12r} \text{ acting downwards}$$

33. (b) : $r = \frac{mv}{qB}$ and $\lambda = \frac{h}{mv} = \frac{h}{rqB}$

$$\lambda = \frac{6.63 \times 10^{-34}}{(0.83 \times 10^{-2}) \times (2 \times 1.6 \times 10^{-19}) \times 0.25}$$

$\lambda \approx 0.01 \times 10^{-10}$ m = 0.01 Å

34. (a) : The moment of inertia of circular ring whose axis of rotation is passing through its centre is,

$I = mR^2$

$\therefore \quad I_1 = m_1R^2$

and $I_2 = m_2(nR)^2$

Since, both have same density.

$$\therefore \quad \frac{m_2}{2\pi(nR) \times A} = \frac{m_1}{2\pi R \times A}$$

where A is cross-section area of ring.

$\therefore \quad m_2 = nm_1$

$$\because \quad \frac{I_1}{I_2} = \frac{m_1R^2}{m_2(nR)^2} = \frac{m_1R^2}{m_1n(nR)^2} = \frac{1}{n^3}$$

$$\because \quad \frac{I_1}{I_2} = \frac{1}{8} \text{ (Given)} \quad \therefore \quad \frac{1}{8} = \frac{1}{n^3} \text{ or } n = 2$$

35. (c) : As $\frac{C_P}{C_V} = \gamma$

$$\therefore \quad \frac{C_P - C_V}{C_V} = \gamma - 1$$

or $C_V = \frac{C_P - C_V}{\gamma - 1} = \frac{R}{\gamma - 1}$

$$\Delta U = nC_V dT = n\frac{RdT}{(\gamma - 1)} = \frac{nPdV}{\gamma - 1}$$

$$= \frac{nP(2V - V)}{\gamma - 1} = \frac{nPV}{\gamma - 1}$$

As $\quad n = 1$

$$\therefore \quad \Delta U = \frac{PV}{(\gamma - 1)}$$

36. (d) : In the circuit, zener diode is used as voltage regulator. Therefore, the output voltage $V_0 = 6$ V, which is the potential across the zener diode.

37. (b) : Let ϕ be the initial phase between two SHMs. Then

$x_1 = A\sin\omega t$ and $x_2 = A\sin(\omega t + \phi)$

$x_2 - x_1 = A\sqrt{2} = A\sin(\omega t + \phi) - A\sin\omega t$

or $\sqrt{2}A = 2A\cos\left(\frac{\omega t + \phi + \omega t}{2}\right)\sin\left(\frac{\omega t + \phi - \omega t}{2}\right)$

or $\sqrt{2}A = 2A\cos\left(\omega t + \frac{\phi}{2}\right)\sin\frac{\phi}{2}$

For maximum value, $\cos\left(\omega t + \frac{\phi}{2}\right) = 1$

$\therefore \quad 2\sin\frac{\phi}{2} = \sqrt{2}$

or $\sin\frac{\phi}{2} = \frac{1}{\sqrt{2}} = \sin\frac{\pi}{4}$ or $\frac{\phi}{2} = \frac{\pi}{4}$ or $\phi = \frac{\pi}{2}$

38. (b) : $\mu = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{d}{x}$

Due to 1st liquid, $\sqrt{2} = \frac{d}{x_1}$

$\therefore \quad x_1 = \frac{d}{\sqrt{2}}$

Due to the IInd liquid, $\mu = \frac{d}{x_2}$

$\therefore \quad x_2 = \frac{d}{\mu}$

$\therefore$ Total apparent depth $= x_1 + x_2 = \frac{d}{\sqrt{2}} + \frac{d}{\mu}$

Total apparent depth $= \frac{d(\mu + \sqrt{2})}{\mu\sqrt{2}}$

39. (d) : Here, $\lambda_0 = 250$ nm $= 250 \times 10^{-9}$ m

$\lambda = 200$ nm $= 200 \times 10^{-9}$ m

According to Einstein's photoelectric equation

$K = h\upsilon - h\upsilon_0$

$$= \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

$$= 6.63 \times 10^{-34} \times 3 \times 10^8 \times \left[\frac{1}{200} - \frac{1}{250}\right] \times \frac{1}{10^{-9}}$$

$\therefore \quad K = 19.89 \times 10^{-20}$ J

40. (c)

41. (b) : The given arrangement of nine plates is equivalent to the parallel combination of 8 capacitors.

The capacity of each capacitor is

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.854 \times 10^{-12} \times 5 \times 10^{-4}}{0.885 \times 10^{-2}} = 0.5 \text{ pF}$$

The capacity of 8 capacitors = $8C = 8 \times 0.5$ pF = 4 pF

42. (b) : Given, $\Delta T = \frac{0.5}{100}T = 2$

or $T = \frac{2 \times 100}{0.5} = 400 \text{ K} = (400 - 273) = 127°\text{C}$

43. **(d)**: $R = \frac{v^2 \sin 2\theta}{g}$

or $\sin 2\theta = \frac{gR}{v^2}$ or $2\theta = \sin^{-1}\left[\frac{gR}{v^2}\right]$

or $\theta = \frac{1}{2}\sin^{-1}\left[\frac{gR}{v^2}\right]$

44. **(a)** : Here both source and the observer approaching each other.

$$\upsilon = \frac{600\left(v + \frac{v}{15}\right)}{\left(v - \frac{v}{10}\right)}$$

$$\upsilon = \frac{600 \times \frac{16}{15}}{\frac{9}{10}}$$

$\upsilon \approx 710$ Hz

45. **(b)**: Let T be the final temperature.
According to principle of calorimetry,
$200 \times 1 \times (T - 20) + 20 \times (T - 20) = 440(92 - T)$
Solving, we get $T = 68°C$